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# Fatty acid composition of Swedish bakery products, with emphasis on *trans*-fatty acids

Sofia Trattner [a,b], Wulf Becker [a,*], Sören Wretling [a], Veronica Öhrvik [a], Irene Mattisson [a]

[a] National Food Agency, Box 622, 751 26 Uppsala, Sweden
[b] Department of Food Science, Uppsala BioCenter, Swedish University of Agricultural Sciences, P.O. Box 7051, 75007 Uppsala, Sweden

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ABSTRACT

*Trans*-fatty acids (TFA) have been associated with increased risk of coronary heart disease, by affecting blood lipids and inflammation factors. Current nutrition recommendations emphasise a limitation of dietary TFA intake. The aim of this study was to investigate fatty acid composition in sweet bakery products, with emphasis on TFA, on the Swedish market and compare fatty acid composition over time. Products were sampled in 2001, 2006 and 2007 and analysed for fatty acid composition by using GC. Mean TFA levels were 0.7% in 2007 and 5.9% in 2001 of total fatty acids. In 1995–97, mean TFA level was 14.3%. In 2007, 3 of 41 products had TFA levels above 2% of total fatty acids. TFA content had decreased in this product category, while the proportion of saturated (SFA) and polyunsaturated (PUFA) fatty acids had increased, mostly through increased levels of 16:0 and 18:2 n-6, respectively. The total fat content remained largely unchanged.


## 1. Introduction

Natural *trans*-fatty acids (TFA) are produced by bio hydrogenation in the rumen of ruminants and occur naturally in ruminant meat (beef, lamb, goat) and dairy products at up to about 5% of total fatty acids (FA) (Lindmark-Månsson, Fonden, & Pettersson, 2003; Nuernberg et al., 2005). During industrial hydrogenation of oils, TFA are produced from *cis*-unsaturated fatty acids during heating and in the presence of hydrogen and metal catalysts. Partially hydrogenated oils (containing TFA) were introduced in the food industry due to their longer shelf-life, oxidative stability and semi-solidity at room temperature (Mozaffarian, Katan, Ascherio, Stampfer, & Willett, 2006). In a European study of 1998, the TFA levels (produced during industrial hydrogenation) were reported to be up to 20% in margarines and up to 50% of total FA in frying oil; in butter, approximately 5% of total FA was TFA (Aro, Amaral et al., 1998). TFA used to be present in products containing vegetable-based spreads containing partially hydrogenated oils, such as bakery products (cakes and cookies), but also in potato chips and popcorn as reported in the 1998 TRANSFAIR study (Aro, van Amelsvoort et al., 1998; van Erp-Baart et al., 1998). Natural TFA, occurring in low amounts in dairy products, can be found in bakery products. Today the TFA level varies, depending on ingredients, and differs among countries. In the TRANSFAIR study, Sweden was reported to be the country with the highest intake of total fat derived from bakery products, contributing with 13% of total fat (van Erp-Baart et al., 1998). Currently, the food items with the highest contribution to the total fat intake in Sweden are fats and oils (23%), meat and meat products (21%), milk and dairy products (21%). Bakery products contribute with 9% (NFA, 2012).

High intake of TFA has been associated with increased risk of coronary heart disease (CHD), sudden death, diabetes mellitus and increased markers for systematic inflammation (Mozaffarian et al., 2006). The TFA found in partially hydrogenated oils has been associated with increased risk of CHD and appears to be more potent than SFA in the development of CHD (FAO, 2010). Due to the health risk of TFA, the FAO/WHO recommend a maximum intake of TFA of 1% of energy intake (*E*%), from both ruminant and industrially-produced sources (FAO, 2010). The current Nordic Nutrition Recommendations recommend a limitation of both SFA and TFA, emphasising that TFA should be limited as much as possible (NNR, 2014). In Denmark, TFA has been regulated and national legislation allows a maximum of 2% TFA of total fat in products containing non-dairy fat. In the United States and Canada, mandatory labelling of TFA content was introduced in 2003 (Krettek, Thorpenberg, & Bondjers, 2008). In Sweden and the EU, labelling of products containing industrial hydrogenated vegetable oils is mandatory (European Union, 2011).

In this project, levels of FA in selected products on the Swedish market in 2001, 2006 and 2007 were determined and compared

* Corresponding author.

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with data from 1995 to 1997 reported in the Swedish part of the TRANSFAIR study (Becker, 1998). Sweet bakery products, cakes, biscuits and cookies, were sampled, since the main fat source in these products is industrially processed fat and oil (van Erp-Baart et al., 1998). The aim was to obtain an overview of TFA levels in the products on the Swedish market and to follow trends in FA composition over time. In order to support decision making for consumers and to evaluate the need for legislations, or not, there is a need to study the FA-profiles of a range of products, that have previously been major contributors to the total TFA intake.

## 2. Materials and methods

### 2.1. Food sampling

In total, 78 samples were collected from shops in Uppsala, Sweden, or sent directly to the National Food Agency (NFA) by the manufacturer. Samples were collected in 2001, 2006 and 2007 and FA were analysed during the same year. Bakery products, which previously have been shown to have high contents of TFA (cakes, biscuits, cookies), were prioritised (Becker, 1998; Torelm, 2004). Samples of the same product category/type, but from various producers, were analysed as separate samples. Product names and sampling times are given in Table 1, together with total fat content and SFA, MUFA (monounsaturated fatty acids), PUFA and TFA. Three gluten-free products (chocolate, digestive, and ginger biscuits), included in the 2006 project were also included in the 2007 project, as manufacturers had changed the fat ingredient.

### 2.2. Sample handling and lipid analysis

About 400–800 g of the food sample were homogenised. A portion of the homogenised duplicate samples was extracted with methanol:chloroform according to Folch, Lees, and Solane-Stanley (1957). The lipid extract was converted into fatty acid methyl esters (FAME) by incubation with 0.01 M sodium hydroxide in methanol at 60–65 °C, for 30 min, followed by collection of the FAME dissolved in hexane. The FAME were separated with a GC (Agilent 6890) equipped with a polar fused capillary column, split injector (split ratio: 50 ml/min) and flame ionisation detector (FID). The temperature programme started at 100 °C for 1 min, and increased at 15 °C/min up to 160 °C, thereafter at 4 °C/min up to 210 °C and held at 210 °C for 12 min. The carrier gas was helium (initial pressure 80 kPa) and the makeup gas was nitrogen. Individual fatty acids were identified with an external standard (68A or St-85 Nu Check, Minnesota, USA) and retention times. Injector and detector temperature were set to 275 and 250 °C, respectively. In addition, the TFA that was detected in 2006 and 2007 was separated on a 100 m CP SIL-88 fused silica capillary column, with a temperature programme started at 175 °C for 60 min, increased at 10 °C/min up to 210 °C and kept at 210 °C for 51 min. The carrier gas was helium (initial pressure 180 kPa and split ratio 40 ml/min). Individual TFAs were identified by external standard (K 110 Alltech-Applied Science Labs, USA) and retention times. All FAs were expressed as % of total FA. The method used for analyses of fatty acid has been accredited (ISO/IEC) since 1995 by SWEDAC (Swedish Board for Accreditation and Conformity Assessment). The quality of the analytical work is ensured continuously in the form of blank samples, control samples and analysing certified reference materials. The detection limit was 0.03%. The Chemistry Division 2 at the NFA coordinated the fat content analyses, which were sent for external analysis. The fat content analyses in 2001 and 2006 were done by the National Veterinary Institute in Uppsala. The total fat content was analysed gravimetrically by the EU-method (EG Directive 98/64/EG method-B). Samples analysed in 2007 were sent to ALcontrol Laboratories, (ALcontrol AB, accredited laboratory) in Linköping. The total fat content was analysed by the gravimetric method NMKL 131, fat, determination by SBR in meat (NMKL, 1989). In intermediate time, samples were stored at −20 °C.

### 2.3. Evaluation of data

In order to follow trends in FA over time, results were compared with data from the Swedish part of the TRANSFAIR study (Becker, 1998) and analyses from two subsequent NFA surveys (Mattisson, Gard, Staffas, & Åstrand, 2009; Wallin, Wretling, & Mattisson, 2009). To compare differences over time, mean values were used if the product was analysed from more than one producer; this was necessary as samples from 1995 to 97 were pooled in equal amounts prior to analysis.

## 3. Results

### 3.1. Fat content and fatty acids

The fat content for each sample and the percentages of total SFA, MUFA, PUFA and individual TFA are presented in Table 1; all data are expressed as % of total FA. Data are only shown, if the FA was present at >0.5% of total FA in at least one product; if the FA are present in one product >0.5%, lower values may be present for this FA in other products. For TFA, all values are included. The mean TFA level in bakery products analysed in 2001 was 5.9% of total fatty acids, compared with 0.7% in products analysed in 2007. Values for individual products ranged from non-detectable to about 14% in both periods. In 2001, 27 of 34 products (79%) had TFA levels higher than 2% while, in 2007, only 3 of 41 products (7%) exceeded this level. The three gluten-free biscuits analysed in 2006 had TFA levels above 2%, but after reformulation TFA levels were 0.5–0.7% (Table 1).

### 3.2. Comparison of products

Table 2 shows total fat content, and percentage of SFA, MUFA, PUFA, TFA, and 18:2 n-6 from products analysed at more than one time point, 1995–97 (Becker, 1998), 2001, 2006 and 2007. For TFA, the amount expressed in g/100 g of product is also given. The total fat content was largely unchanged over time. The levels of TFA, expressed both as percentage of total FA and in g/100 g product, decreased from 1998 and 2001 compared to 2006 and 2007. During the same period, the percentage of SFA had increased. In total, the levels of MUFA and PUFA remained stable; however, in some products, percentage of PUFA increased, mainly as linoleic acid (18:2 n-6) (Table 2).

## 4. Discussion

In general, the levels of TFA in the sampled product categories on the Swedish market decreased during the years from 1995–97 to 2007. Mean TFA level in products/product categories analysed, in the Swedish TRANSFAIR study of 1995–7, was 14.3%, compared to 5.9% and 0.7% in products analysed in 2001 and 2007, respectively. In the TRANSFAIR study, products of the same category/type were, in such cases, merged into one aggregated analytical sample, representing 2–5 different brands, mixed according to market shares, where available. In the present study, samples of the same product type were analysed separately. In 1995–97 TFA levels higher than 2% of total FA were detected in 20 of 21 products (aggregates), compared to 3 of 41 products in 2007.

**Table 1**
Descriptive product name, year of analysis, total fat content (g/100 g), Total SFA, MUFA, PUFA and some individual FAs expressed as % of total FA.

| Product | Year | Fat | SFA | MUFA* | PUFA* | 18:2 n-6 | 18:3 n-3 | 14:1t | 16:1t | 18:1t | 20:1t | 18:3t | 18:2t | Total TFA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Almond bun | 2001 | 13.6 | 48.3 | 36.9 | 14.7 | 12.0 | 2.50 | nd | nd | 0.33 | nd | 0.10 | 0.35 | 0.79 |
| Almond bun | 2007 | 12.7 | 60.1 | 24.2 | 14.7 | 10.6 | 2.90 | nd | nd | nd | nd | nd | nd | nd |
| Almond bun | 2007 | 19.0 | 46.3 | 36.1 | 17.4 | 13.0 | 4.00 | nd | nd | 0.32 | nd | nd | nd | 0.32 |
| American muffins | 2001 | 24.3 | 9.58 | 60.5 | 28.7 | 20.4 | 7.87 | nd | 0.21 | nd | nd | 0.30 | 0.07 | 0.57 |
| Biscuits Ballerina | 2001 | 20.7 | 47.4 | 44.1 | 7.42 | 4.56 | 0.26 | nd | 0.19 | 8.5 | nd | 0.26 | 1.78 | 10.7 |
| Biscuits Ballerina | 2007 | 22.9 | 63.1 | 26.6 | 9.45 | 8.50 | 0.62 | nd | nd | nd | nd | nd | nd | nd |
| Biscuits Brago | 2001 | 18.4 | 26.4 | 64.8 | 8.41 | 5.19 | 0.22 | nd | nd | 30.0 | nd | 0.41 | 2.00 | 32.4 |
| Biscuits Brago | 2007 | 21.3 | 38.7 | 46.9 | 14.0 | 13.0 | 0.88 | nd | nd | nd | nd | nd | nd | nd |
| Biscuits Finger Marie | 2007 | 15.9 | 47.8 | 38.2 | 12.7 | 11.5 | 0.27 | nd | nd | nd | nd | nd | 0.84 | 0.84 |
| Biscuits Marie | 2001 | 12.8 | 41.3 | 44.7 | 13.1 | 12.2 | 0.51 | nd | 0.07 | 5.4 | nd | 0.05 | 0.24 | 5.7 |
| Biscuits Marie | 2007 | 12.3 | 38.3 | 45.2 | 15.3 | 14.2 | 0.97 | nd | nd | nd | nd | nd | nd | nd |
| Biscuits Singoalla | 2001 | 18.9 | 52.2 | 40.1 | 7.21 | 4.40 | 0.34 | nd | 0.12 | 9.0 | nd | nd | 1.28 | 10.5 |
| Biscuits Singoalla | 2007 | 21.6 | 63.5 | 26.8 | 9.59 | 8.73 | 0.75 | nd | nd | nd | nd | nd | nd | nd |
| Biscuits wholemeal Oat Bits | 2001 | 20.6 | 42.6 | 42.7 | 14.1 | 13.3 | 0.42 | nd | 0.12 | 7.8 | nd | 0.07 | 0.24 | 8.2 |
| Biscuits wholemeal Oat Bits | 2007 | 14.7 | 27.0 | 35.0 | 36.4 | 34.9 | 1.25 | nd | nd | nd | nd | nd | 0.45 | 0.45 |
| Break bar gluten-free | 2007 | 31.5 | 64.1 | 30.6 | 4.47 | 3.58 | 0.38 | nd | nd | 0.33 | nd | nd | nd | 0.33 |
| Caramel biscuits | 2007 | 26.7 | 45.5 | 41.7 | 12.7 | 10.5 | 1.60 | nd | nd | nd | nd | nd | 0.60 | 0.60 |
| Chocolate ball | 2001 | 31.2 | 50.1 | 39.4 | 10.4 | 8.67 | 1.25 | nd | 0.11 | 6.9 | nd | 0.13 | 0.15 | 7.3 |
| Chocolate ball | 2007 | 32.1 | 59.3 | 29.4 | 11.4 | 9.83 | 1.49 | nd | nd | nd | nd | nd | nd | nd |
| Chocolate bar filled wafers covered with milk chocolate | 2007 | 27.4 | 69.0 | 26.0 | 4.65 | 4.05 | 0.25 | nd | nd | nd | nd | nd | nd | nd |
| Chocolate bar filled wafers covered with milk chocolate gluten-free | 2007 | 33.9 | 52.8 | 38.5 | 8.11 | 6.58 | 0.80 | nd | nd | 0.25 | nd | nd | 0.28 | 0.53 |
| Chocolate biscuits gluten-free | 2007 | 31.2 | 47.1 | 39.7 | 11.8 | 9.6 | 1.46 | nd | nd | nd | nd | nd | 0.49 | 0.49 |
| Chocolate biscuits gluten-free | 2006 | 25.1 | 38.1 | 50.1 | 9.8 | 7.8 | 2.01 | nd | nd | 14.3 | nd | nd | 0.47 | 14.8 |
| Chocolate chip biscuits gluten free pepitas | 2007 | 22.1 | 60.6 | 29.0 | 10.1 | 8.62 | 1.39 | nd | nd | nd | nd | nd | nd | nd |
| Chocolate chip cookies | 2007 | 29.6 | 60.7 | 31.2 | 8.13 | 6.91 | 0.94 | nd | nd | nd | nd | nd | 0.24 | 0.24 |
| Chocolate cookies | 2001 | 22.9 | 46.1 | 43.9 | 10.0 | 7.73 | 1.71 | nd | 0.38 | 7.8 | nd | 0.18 | 0.15 | 8.5 |
| Chocolate cream filled wafers gluten-free | 2007 | 30.4 | 61.1 | 27.7 | 9.64 | 8.13 | 0.57 | nd | nd | nd | nd | nd | nd | nd |
| Chocolate layer cake filled with apricot jam glazed with chocolate | 2001 | 25.3 | 64.7 | 29.1 | 5.08 | 3.42 | 0.45 | 0.23 | 0.48 | 2.11 | nd | 0.10 | 0.13 | 3.0 |
| Chocolate pastry soft almond macaroon bottom with buttercream covered in chocolate | 2001 | 28.6 | 53.7 | 33.0 | 12.4 | 10.6 | 1.48 | nd | 1.16 | 1.19 | nd | nd | nd | 1.36 |
| Chocolate Swiss roll with butter cream | 2001 | 16.5 | 45.6 | 41.8 | 12.4 | 9.04 | 2.71 | nd | 0.35 | 6.2 | nd | 0.18 | 0.12 | 6.9 |
| Chocolate Swiss roll with butter cream | 2007 | 17.9 | 58.1 | 27.2 | 13.5 | 10.8 | 1.89 | nd | nd | nd | nd | nd | 0.37 | 0.37 |
| Chocolate Swiss roll with butter cream | 2007 | 16.9 | 44.1 | 34.3 | 19.7 | 13.3 | 5.70 | nd | nd | 0.64 | nd | nd | 0.26 | 0.90 |
| Chocolate toffee covered with chocolate | 2007 | 16.7 | 61.8 | 32.3 | 4.99 | 3.93 | 0.31 | nd | nd | nd | nd | nd | nd | nd |
| Cinnamon croissant | 2007 | 16.8 | 25.5 | 52.7 | 21.6 | 16.7 | 4.68 | nd | nd | 0.44 | nd | 0.36 | 0.34 | 1.14 |
| Cocoa wafers covered with dark chocolate gluten free | 2007 | 26.9 | 74.7 | 21.8 | 3.55 | 3.26 | 0.29 | nd | nd | nd | nd | nd | nd | nd |
| Cookie with short-crust and meringue | 2001 | 30.5 | 47.7 | 38.2 | 13.0 | 9.78 | 2.68 | nd | 0.16 | 1.78 | nd | 0.07 | 0.28 | 2.29 |
| Cookies assorted | 2001 | 21.4 | 43.7 | 44.1 | 12.1 | 9.74 | 1.71 | nd | 0.40 | 6.1 | nd | 0.31 | 0.30 | 7.0 |
| Cookies "bondkakor" | 2007 | 23.1 | 46.8 | 39.5 | 14.0 | 11.8 | 1.78 | nd | nd | nd | nd | nd | 0.48 | 0.48 |
| Crème-filled wafers chocolate | 2007 | 29.7 | 95.4 | 1.96 | 1.44 | 0.54 | nd | nd | nd | nd | nd | nd | nd | nd |
| Crème-filled wafers vanilla | 2007 | 28.7 | 99.0 | 0.46 | 0.50 | 0.50 | nd | nd | nd | nd | nd | nd | nd | nd |
| Danish pastry bake-off | 2007 | 25.7 | 44.6 | 42.8 | 12.5 | 9.60 | 2.28 | nd | nd | 2.15 | nd | nd | 0.19 | 2.34 |
| Danish pastry bake-off | 2007 | 27.6 | 47.0 | 38.7 | 13.4 | 10.9 | 1.94 | nd | nd | nd | nd | nd | nd | nd |
| Danish pastry bake-off | 2007 | 29.6 | 46.0 | 40.1 | 13.8 | 12.1 | 1.01 | nd | nd | 1.40 | nd | nd | 0.83 | 2.23 |
| Danish pastry filled with vanilla custard jam powdered sugar | 2001 | 27.3 | 47.3 | 40.8 | 11.7 | 9.15 | 2.26 | nd | 0.21 | 3.45 | nd | 0.08 | 0.44 | 4.2 |
| Digestive biscuits gluten-free | 2007 | 20.2 | 44.3 | 41.7 | 12.7 | 10.6 | 1.41 | nd | nd | nd | nd | nd | 0.72 | 0.72 |
| Digestive biscuits wholegrain gluten-free | 2006 | 16.1 | 41.5 | 45.1 | 12.3 | 10.3 | 2.07 | nd | nd | 6.1 | nd | nd | 0.64 | 6.7 |
| Digestive biscuits | 2007 | 21.2 | 39.1 | 45.7 | 14.2 | 13.2 | 0.89 | nd | nd | nd | nd | nd | nd | nd |
| Digestive biscuits | 2007 | 18.6 | 30.0 | 47.5 | 22.2 | 18.8 | 3.18 | nd | nd | nd | nd | 0.27 | 0.47 | 0.74 |
| Digestive biscuits | 2007 | 24.7 | 53.5 | 36.5 | 9.98 | 9.46 | 0.27 | nd | nd | nd | nd | nd | 0.24 | 0.24 |
| Digestive biscuits wholegrain 23% | 2001 | 19.8 | 41.9 | 44.6 | 12.1 | 11.1 | 0.41 | nd | nd | 6.8 | nd | nd | 0.29 | 7.1 |
| Doughnut filled with apple sauce vanilla custard | 2001 | 13.2 | 44.3 | 43.3 | 12.2 | 10.3 | 1.06 | nd | 0.31 | 4.3 | nd | 0.18 | 0.43 | 5.2 |
| Doughnut without filling | 2001 | 25.9 | 37.8 | 49.6 | 12.2 | 9.41 | 1.08 | nd | 0.23 | 5.5 | nd | 0.19 | 1.11 | 7.0 |

(*continued on next page*)

**Table 1** (*continued*)

| Product | Year | Fat | SFA | MUFA* | PUFA* | 18:2 n-6 | 18:3 n-3 | 14:1t | 16:1t | 18:1t | 20:1t | 18:3t | 18:2t | Total TFA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Filled chocolate wafer gluten-free | 2007 | 24.8 | 50.1 | 37.8 | 11.5 | 11.0 | 0.38 | nd | nd | nd | nd | nd | 0.39 | 0.39 |
| Filled wafers biscuits | 2001 | 29.9 | 98.3 | 0.91 | 0.78 | 0.72 | 0.06 | nd | nd | 0.20 | nd | nd | nd | 0.20 |
| Finnish cookies | 2007 | 29.5 | 55.6 | 32.4 | 12.0 | 10.1 | 1.57 | nd | nd | nd | nd | nd | nd | nd |
| Fruit torte raspberry jam vanilla custard almond paste fruit and jelly | 2001 | 7.46 | 30.3 | 50.6 | 17.8 | 17.0 | 0.14 | nd | 0.10 | 5.1 | nd | nd | nd | 5.25 |
| Ginger biscuit gluten-free | 2007 | 14.7 | 57.4 | 29.7 | 12.4 | 10.5 | 1.28 | nd | nd | nd | nd | nd | 0.50 | 0.50 |
| Ginger biscuit gluten-free | 2006 | 16.2 | 55.4 | 35.3 | 8.5 | 6.8 | 1.35 | nd | nd | 4.2 | nd | nd | 0.52 | 4.7 |
| Ice cream sauce chocolate Ohoj | 2007 | 6.72 | 56.3 | 37.0 | 6.52 | 6.29 | 0.15 | nd | nd | nd | nd | nd | nd | nd |
| Layer cake filled with berries whipped cream vanilla custard jam glazed with jelly | 2001 | 11.1 | 59.5 | 33.9 | 6.09 | 4.14 | 0.63 | 0.28 | 0.62 | 5.7 | nd | 0.12 | 0.27 | 7.0 |
| Layer cake filled with whipped cream vanilla custard raspberry jam covered with marzipan | 2001 | 13.8 | 52.0 | 37.2 | 10.1 | 8.28 | 0.78 | 0.23 | 0.47 | 4.7 | nd | 0.20 | 0.37 | 6.0 |
| Layer cream cake filled with strawberries banana whipped cream | 2001 | 11.7 | 65.2 | 28.7 | 5.5 | 3.39 | 0.70 | 0.30 | 0.47 | 2.88 | nd | 0.31 | 0.34 | 4.30 |
| Meringue with chocolate | 2001 | 0.74 | 81.5 | 14.9 | 1.47 | 1.33 | 0.15 | nd | nd | 4.62 | nd | nd | nd | 4.62 |
| Milk chocolate with almond caramel centre | 2007 | 32.5 | 59.2 | 33.2 | 7.36 | 6.56 | 0.63 | nd | nd | nd | nd | nd | nd | nd |
| Napoleon cake with whipped cream vanilla custard raspberry jam glazing | 2001 | 20.6 | 57.1 | 34.2 | 8.11 | 5.67 | 1.38 | 0.17 | 0.41 | 3.54 | nd | 0.13 | 0.68 | 4.94 |
| Oat biscuits gluten-free | 2007 | 20.1 | 43.1 | 42.3 | 14.3 | 12.3 | 1.41 | nd | nd | 0.49 | nd | nd | 0.68 | 1.17 |
| Pastry with almond dough and chocolate | 2001 | 31.4 | 44.9 | 41.9 | 12.8 | 10.8 | 1.39 | nd | 0.17 | 5.19 | nd | nd | 0.08 | 5.43 |
| Potato pastry with vanilla custard butter cream marzipan | 2001 | 16.8 | 40.9 | 45.4 | 13.7 | 12.3 | 0.77 | nd | 0.10 | 3.20 | nd | 0.24 | 0.18 | 3.72 |
| Shortcrust pastry filled with almond dough glazed | 2001 | 20.6 | 53.7 | 33.0 | 12.4 | 13.2 | 2.45 | nd | 0.18 | 0.26 | nd | nd | nd | 0.44 |
| Solena energy bar | 2007 | 11.9 | 47.6 | 42.0 | 10.4 | 10.1 | 0.21 | nd | nd | nd | nd | nd | nd | nd |
| Sponge cake and gingerbread cake | 2001 | 15.9 | 9.31 | 58.7 | 30.2 | 20.2 | 9.47 | nd | 0.28 | nd | nd | 0.31 | nd | 0.59 |
| Swedish punch (or arrak) roll | 2001 | 20.2 | 38.0 | 45.7 | 16.1 | 15.1 | 0.93 | nd | 0.26 | 2.16 | nd | 0.08 | 0.13 | 2.63 |
| Swedish punch (or arrak) roll | 2007 | 19.4 | 50.2 | 35.1 | 14.6 | 13.1 | 1.51 | nd | nd | 0.21 | nd | nd | nd | 0.21 |
| Sweet wheat bread filled | 2001 | 10.3 | 39.6 | 43.3 | 17.0 | 13.6 | 3.26 | 0.08 | 0.51 | 1.56 | nd | 0.24 | 0.11 | 2.50 |
| Sweet wheat bun filled with almond paste and whipped cream | 2001 | 16.3 | 55.5 | 35.1 | 9.22 | 7.13 | 1.21 | 0.20 | 0.30 | 3.86 | nd | 0.13 | 0.32 | 4.81 |
| Swiss roll with jam | 2001 | 14.9 | 54.8 | 34.5 | 10.5 | 7.67 | 2.39 | nd | 0.10 | 5.06 | nd | 0.11 | 0.21 | 5.48 |
| Wheat wholemeal rusks | 2001 | 6.17 | 16.4 | 60.1 | 21.6 | 16.3 | 1.11 | nd | 0.04 | 9.7 | nd | 0.49 | 3.32 | 13.6 |
| Wheat wholemeal rusks krisprolls | 2007 | 8.51 | 16.9 | 61.8 | 21.1 | 14.1 | 1.18 | nd | nd | 10.8 | nd | nd | 3.27 | 14.1 |

nd = not detected. Detection limit = 0.03%.

T = *trans*, tTFA = total *trans*-fatty acids, GL = gluten free.

* MUFA and PUFA from 2001 also include total *trans*-fatty acids. 2006 and 2007 values for *cis*- and *trans*-MUFA and *trans*-PUFA are separated.

**Table 2**
Fat content (g/100 g), SFA, MUFA, PUFA, 16:0, 18:2 n-6 and TFA expressed as % of total FA in products analysed in at least two of the four sampling points, 1998, 2001, 2006 and 2007. For TFA, values are also expressed in g/100 g of product.

| Product | Year | Total fat g/100 g | SFA % of FA | 16:0 % of FA | MUFA* % of FA | PUFA* % of FA | 18:2n6 % of FA | Total TFA | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | % of FA | g/100 g |
| Almond bun | 2007 | 16.7 | 53.2 | 21.5 | 30.0 | 15.9 | 11.8 | 0.16 | 0.03 |
| | 2001 | 13.6 | 48.2 | 27.2 | 36.9 | 14.7 | 12.0 | 0.79 | 0.10 |
| | 1995–97 | 12.7 | 29.9 | 16.9 | 41.3 | 13.8 | 10.6 | 13.4 | 1.62 |
| Biscuits Ballerina | 2007 | 24.2 | 63.1 | 16.9 | 26.5 | 9.3 | 8.5 | nd | nd |
| | 2001 | 20.7 | 47.5 | 8.43 | 44 | 7.4 | 4.6 | 10.7 | 2.10 |
| Biscuits Brago | 2007 | 22.4 | 38.7 | 24.8 | 46.9 | 14.0 | 13.0 | nd | nd |
| | 2001 | 18.4 | 26.3 | 13.1 | 64.7 | 8.4 | 5.2 | 32.4 | 5.7 |
| Biscuits Guld Marie | 2007 | 13.0 | 38.3 | 24.5 | 45.2 | 15.3 | 14.2 | nd | nd |
| | 2001 | 12.8 | 41.2 | 27.2 | 44.7 | 13.1 | 12.2 | 5.7 | 0.70 |
| | 1995–97 | 10.8 | 33.2 | 23.8 | 35.3 | 9.0 | 8.6 | 22.2 | 2.28 |
| Biscuits Singoalla | 2007 | 22.6 | 63.5 | 18.8 | 26.8 | 9.6 | 8.7 | nd | nd |
| | 2001 | 18.9 | 52.2 | 8.3 | 40.1 | 7.1 | 4.4 | 10.5 | 1.88 |
| Chocolate ball | 2007 | 33.5 | 59.3 | 26.5 | 29.4 | 11.4 | 9.8 | nd | nd |
| | 2001 | 31.2 | 50.1 | 24.8 | 39.4 | 10.4 | 8.7 | 7.3 | 2.16 |
| Chocolate biscuits gluten free | 2007 | 33.1 | 47.1 | 36.2 | 39.7 | 11.8 | 9.6 | 0.49 | 0.15 |
| | 2006 | 25.1 | 38.1 | 21.5 | 50.1 | 9.8 | 7.8 | 14.8 | 3.53 |
| Chocolate chip cookies | 2007 | 31.0 | 60.7 | 30.8 | 31.2 | 8.1 | 6.9 | 0.24 | 0.07 |
| | 2001 | 22.9 | 45.7 | 24.9 | 43.7 | 9.9 | 7.7 | 8.5 | 1.84 |
| Chocolate Swiss roll with butter cream | 2007 | 18.5 | 51.1 | 25.3 | 30.6 | 16.4 | 12.0 | 0.63 | 0.11 |
| | 2001 | 16.5 | 45.7 | 18.9 | 41.6 | 12.4 | 9.0 | 6.9 | 1.08 |
| | 1995–97 | 20.5 | 39.1 | 14.5 | 32.6 | 9.0 | 8.6 | 16.8 | 3.27 |
| Creme filled wafers | 2007 | 30.7 | 97.2 | 9.35 | 1.11 | 1.0 | 0.5 | nd | nd |
| | 2001 | 29.9 | 98.4 | 10.2 | 0.91 | 0.8 | 0.7 | 0.20 | 0.06 |
| | 1995–97 | 27.5 | 21.1 | 10.5 | 39.3 | 1.6 | 1.5 | 37.4 | 9.8 |
| Danish pastry bake off | 2007 | 29.0 | 45.9 | 36.1 | 40.5 | 13.2 | 10.8 | 1.52 | 0.42 |
| | 2001 | 27.3 | 47.1 | 35.9 | 40.3 | 11.7 | 9.2 | 4.2 | 1.08 |
| | 1995–97 | 27.0 | 41.2 | 30.7 | 40.6 | 9.9 | 8.5 | 8.9 | 2.28 |
| Digestive biscuits | 2007 | 22.6 | 40.9 | 32.5 | 43.2 | 15.5 | 13.8 | 0.32 | 0.07 |
| | 2001 | 19.8 | 41.9 | 29.0 | 44.6 | 12.0 | 11.1 | 7.1 | 1.34 |
| | 1995–97 | 21.0 | 34.6 | 26.5 | 37.9 | 7.9 | 7.7 | 19.2 | 3.83 |
| Digestive biscuits gluten free | 2007 | 21.4 | 44.3 | 37.7 | 41.7 | 12.7 | 10.6 | 0.72 | 0.15 |
| | 2006 | 16.1 | 49.5 | 31.1 | 45.1 | 12.3 | 10.3 | 6.7 | 1.02 |
| Doughnut filled | 2001 | 13.2 | 44.3 | 29.8 | 43.2 | 12.2 | 10.3 | 5.19 | 0.65 |
| | 1995–97 | 9.1 | 22.9 | 13.3 | 48.0 | 8.3 | 7.3 | 17.3 | 1.50 |
| Ginger biscuit | 2007 | 14.7 | 57.4 | 34.6 | 29.7 | 12.4 | 10.5 | 0.50 | 0.07 |
| | 2006 | 16.2 | 55.4 | 30.7 | 35.3 | 8.5 | 6.8 | 4.70 | 0.72 |
| | 1995–97 | 15.9 | 38.1 | 14.0 | 38.2 | 9.2 | 8.1 | 13.9 | 2.10 |
| Oat Bits (Hob-nobs) | 2007 | 15.6 | 27.0 | 22.2 | 35.0 | 36.4 | 34.9 | 0.53 | 0.08 |
| | 2001 | 20.6 | 42.4 | 33.8 | 42.7 | 14.1 | 13.3 | 8.2 | 1.60 |
| Swedish macaroon teacake (Mazarin) | 2001 | 20.6 | 41.8 | 21.2 | 41.6 | 15.9 | 13.2 | 0.44 | 0.09 |
| | 1995–97 | 24.5 | 29.0 | 14.3 | 44.2 | 15.2 | 13.4 | 9.4 | 2.19 |
| Swedish punch (or arrak) roll | 2007 | 20.3 | 50.2 | 20.1 | 35.1 | 14.6 | 13.0 | 0.21 | 0.04 |
| | 2001 | 20.2 | 38.0 | 15.7 | 45.7 | 16.1 | 15.1 | 2.63 | 0.50 |
| Swiss roll filled with jam | 2001 | 14.9 | 54.8 | 18.2 | 34.5 | 10.5 | 7.7 | 5.5 | 0.78 |
| | 1995–97 | 14.5 | 36.2 | 13.7 | 31.1 | 12.3 | 10.4 | 18.5 | 2.55 |

TFA = *trans*-fatty acids. nd = not detected.
For descriptive product names see Table 1.
* MUFA and PUFA from 2001 also include total *trans*-fatty acids. 2006 and 2007 values for *cis*- and *trans*-MUFA and *trans*-PUFA are separated.

In the TRANSFAIR study, 18:1t was the main TFA isomer, with a mean level of ca. 12% of total FA, followed by 18:2t, 0.9% (Becker, 1998). In 2001, the average levels of 18:1t and 18:2t were 5% and 0.45%, respectively. In 2007, the use of partially hydrogenated fats had been further limited and mean levels of 18:1t and 18:2t were similar, 0.43% and 0.28% of total FA, respectively, although there were many non-detects. Data from in-house analyses of various spreads and industrial shortenings show levels of 18:2t ranging from n.d. to 0.3% of total FA, with somewhat higher values for butter, around 0.4–0.6% of total fatty acids, in agreement with previous studies (Becker, 1998; Kuhnt, Baehr, Rohrer, & Jahreis, 2011).

In product categories with FA analysis results from more than one year, a trend towards decreased levels of TFA and increased levels of SFA (mainly 16:0), and in some products also PUFA (mainly 18:2 n-6), were seen (Table 2 and Supplementary web material). This shift in FA profile indicates that the use of partially hydrogenated vegetable oils has decreased and that the use of vegetable fats, e.g., palm oil with a high level of SFA (16:0) has increased. The increased levels of PUFA, in particular 18:2 n-6, indicate inclusion of vegetable oils such as sunflower-, corn- or soybean oil. In a subsequent study, carried out in 2008, 109 cookies and biscuits were sampled from local shops in 36 municipalities and analysed for TFA. The sampling was not representative, but focussed on products marketed in smaller local shops that had not been analysed previously (Wallin et al., 2009). Results showed that 19 (17%) of the products contained TFA levels above 2%. Of these, six products contained dairy fat. The remaining 13 products were mainly imported from countries outside the EU. In another study, fatty acid compositions of gluten-free products were analysed (Mattisson et al., 2009). In three samples of cookies TFA content was 5–15% of total FA. After a change in recipes, products were reanalysed and TFA levels were around 0.5% of total FA, and $\leqslant$0.1 g/100 g of product.

The reduced TFA levels in the analysed food products are in agreement with studies reported from other European countries. Results from an Austrian study showed decreased TFA levels in several product categories, including desserts and dough's, which contained, on average, 3.4–3.8%, corresponding to 0.11–0.87 g/100 g of product (Wagner, Plasser, Proell, & Kanzler, 2008). In the UK, TFA levels in bakery products have decreased considerably, with a mean level of 0.11 g/100 g product, ranging from <0.01 to 0.74 g/100 g (Department of Health, 2011). Reported TFA levels in Swiss snacks, cakes and biscuits ranged from 0.6 up to 12.3% (Richter, Albash Shawish, Scheeder, & Colombani, 2009). In Denmark, results from 2010 still demonstrate the presence of TFA in foods. Up to 3 g TFA/100 g of fat were found in Danish products and up to 33 g TFA/100 g of fat were found in imported products; however, in 93% of the analysed products, TFA levels were less than 2 g/100 g of fat (Ærendahl Mikkelsen, Bysted, & Langkilde, 2011).

In the present study, no clear trend was seen for total fat content; however, data for 2007 show slightly higher levels compared to 1995–97 (Table 2). Mostly TFA has been replaced with SFA, but, in some products, increased levels of PUFA are also found, e.g. in some biscuits. In a study including products from 14 countries sampled from 2005 to 2008, French fries, cookies, and cakes with low TFA content had higher contents of SFA, MUFA and PUFA than had corresponding products with previously high contents of TFA (Stender, Asturp, & Dyerberg, 2009). The stability and required sensory properties of the product will limit the FA which can replace TFA.

The decreased levels of TFA in products presented in this paper have contributed to a reduced TFA intake. In the TRANSFAIR study, the average intake of TFA in Sweden during 1995–97 was estimated to be 1.1 *E*% (Hulshof, van Erp-Baart, Anttolainen, Church, et al., 1999). Results, from analyses of market baskets representative of the average annual food supply, show that TFA contributed with 0.6 *E*% in 2005 (Becker, Haglund, & Wretling, 2008) and 0.5 *E*% in 2010, mostly deriving from ruminant sources, e.g. dairy products and beef (NFA, 2012). This is well below the FAO recommendation stating that TFA should contribute with no more than 1 *E*% (FAO, 2010). Similar decreasing trends have been seen in other Nordic countries and the Netherlands (Helldán, Kosonen, & Tapanainen, 2013; Helsedirektoratet, 2012; Pedersen, Fagt, & Velsing Groth, 2010; Thorgeirsdottir, Valgeirsdottir, & Gunnarsdottir, 2011; van Rossum, Fransen, Verkaik-Kloosterman, Buurma-Rethans, & Ocké, 2011).

Overall, there is a common agreement that high intakes of TFA have negative health effects (FAO, 2010). The food source of TFA and its impact on health lead to conflicting conclusions. In a case control study including 512 subjects, the relative risk of myocardial infarction was significantly higher for the highest (5.04 g/d) versus the lowest (0.84 g/d) quintile of energy-adjusted industrial TFA. Energy-adjusted intake of TFA from animal sources was not related to increased risk of myocardial infarction, the lowest quintile was 0.45 g/d and the highest 1.79 g/d (Ascherio et al., 1994). In a review by Brouwer, Wanders, and Katan (2013), a quantitative comparison of the effect of ruminant TFA, CLA and industrial TFA on blood lipids was described. All three TFA classes increased the LDL/HDL ratio, and therefore could contribute to increased risk of CHD; the effect of ruminant TFA was weaker (but not significantly) than the effects by industrial TFA. A Norwegian prospective study, including 71,464 men and women, showed that intake of industrial TFA was associated with an increased risk of CHD, and that intake of ruminant TFA was associated with an increased risk of CHD and CVD in women, but not in men (Laake et al., 2011). In another study, based on data from four Danish cohort studies, ruminant TFA intakes were not associated with increased risk of CHD (Jakobsen, Overvad, Dyerberg, & Heitmann, 2008). In an animal study, *trans*-11 18:1 (*trans*-vaccenic acid, *t*-VA), being one of the most frequent natural TFAs, was directly associated with CHD and inflammation (Wang, Jacome-Sosa, & Proctor, 2012). Chardigny et al. (2008) reported HDL-lowering effects of industrial TFA, but not natural TFA, at intakes around 5 E%. Ruminant TFAs are suggested to up-regulate expression of PPAR$\alpha$ and PPAR$\gamma$, being involved in energy expenditure and lipogenesis (Wang et al., 2012). In the Nurses' Health Study and in the large Finnish alpha-tocopherol, beta carotene study, no negative effects of ruminant TFA on relative risk of CHD were found, but industrial TFA was associated with increased risk of CHD (Pietinen et al., 1997; Willett et al., 1993). Both ruminant and industrial TFA have similar effects on blood lipids (Brouwer et al., 2013) and, with intakes below 1 E%, any difference is not considered a priority public health issue (Willett & Mozaffarian, 2008).

Specific SFAs are claimed to have different health effects. According to FAO/WHO (FAO, 2010), the SFAs with a documented negative effect on CHD are 12:0, 14:0, 16:0, whereas 18:0 is neutral. The current Nordic nutrition recommendations (NNR, 2014) focus on types and food sources of total fat and FA and intakes of both SFA and TFA should be limited and replaced by PUFA and/or MUFA. Also, energy-dense foods high in added fat and sugars should be limited. The present result that TFA was mainly replaced by SFA represents no major nutritional advantage, and general advice to limit the consumption is still valid.

The intake and occurrence of TFA in Sweden, cannot, according to the above mentioned studies, be considered as a health problem for the majority of the population. However, further reductions are possible and intake levels should be monitored. The actions undertaken (following the reported hazards of TFA) to protect consumer health have been different in different countries. In Denmark, TFA levels are regulated by a national legislation allowing a maximum of 2% TFA of the fat in products containing non-dairy fat. In the United States and Canada, mandatory labelling of TFA content was introduced in 2003 (Krettek et al., 2008), although criteria

are based on the TFA amount per portion. In Sweden communication with the industry has resulted in reduced TFA levels. Labelling of products containing industrial hydrogenated vegetable oils is mandatory in Sweden and the EU (European Union, 2011); however, such labels do not indicate TFA values. In view of the documented negative health effects caused by TFA, a regulation of TFA in food, similar to the Danish one, is a viable option. It could also act as a driving force for the industry to further develop new techniques and find alternative raw materials for oils and fats with an appropriate FA composition. This could be necessary, if the use of palm oil, a frequently used substitute for TFA today, is not sustainable.

Limitations in this study are that data from many individual products cannot be compared, since the same products from different producers were pooled in 1995–97; however, average values can be compared. Data from 2001 show total MUFA and PUFA, including both *cis*- and *trans*-FA whereas, in 2006 and 2007, *cis*-MUFA and *cis*-PUFA are reported separately. As a consequence, MUFA and PUFA from 2001 cannot be directly compared with data from 2006 and 2007. In terms of evaluating TFA values in the products the data are still interesting and reliable.

## 5. Conclusion

TFA levels in bakery products and other processed foods in Sweden have decreased between 1995–97 and 2007. The reduction started in the early 1990s with margarines, and, since 2001 the levels in most products have been reduced. A few products sampled in 2007 in this study contained more than 2 g TFA/100 g of fat. However, the TFA content is in general low, and does not cause a health problem today for the general Swedish population. In most products, TFAs have been replaced by SFAs, even if some products showed increased PUFA levels. The general advice to limit consumption of energy-dense foods high in added fat and sugars is still an important message to improve dietary habits.

## Conflict of interest

The authors have no conflict of interest.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodchem.2014.11.145.

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